The Moroccan Association of Agricultural Economics (AMAECO)

in partnership with

International Association of Agricultural Economics (IAAE) **&** **United Nations University-World Institute for Development Economics Research (UNU WIDER)**

Climatic constraints play a predominant role in the performance of national agricultures and their capacity to support economic growth and assure food security for the population. With the climate changes and projected inter and intra annual fluctuations, management of the agricultural sector takes a particular dimension including management of risks inherent in the sector and searching for sustainable growth for the sector. Agricultural policies must permit a continual adaption of the processes of agricultural production and a reduction of negative effects of climate change in order to assure food security for the population.

In the face of climate change, the adaptation strategies can generate important development opportunities. Also, governments have need for pertinent evaluations of the impacts of climate change.

Considering the importance of this problem; to permit an exchange of ideas among professional staff, researchers, and specialists in the domain of development; to contribute to a richer understanding of methods and analytical tools ; and to contribute to better preparation of decision making in this domain – the Moroccan Association of Agricultural Economics (AMAEco) in collaboration with the International Association of Agricultural Economics (IAAE) and the World Institute For Development Economics Research of the United Nations University (UNU-WIDER) are organizing an international conference 6-7 December in Rabat, Morocco under the theme:

« Impacts of climate change on agriculture »

Rabat, Morocco December 6-7, 2011

The principal themes proposed are the following::

1. Analysis of the impacts of climate change on agriculture: simulations and projections
2. **Climate change and sustainability of agricultural production systems**
3. **Adaption strategies for agriculture in the face of climate change: systems of production, risks in agriculture, and policies for food security**
4. **Water management in the context of climate change**

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CONTRIBUTION TO THE ASSESSMENT OF CLIMATE CHANGE VULNERABILITIES IN THE LIVESTOCK SECTOR IN NORTH AFRICA, THE CASE OF MOROCCO

Dr. Fouad Bergigui
African Youth Initiative on Climate Change / MJID Foundation
Tel: +212 664696284 / fax: +212 522266549
13, rue de blida, quartier des hopitaux, Casablanca-Morocco
fouad.bergigui@ayicc.net , f.bergigui@fmjid.ma

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ABSTRACT

Through this paper, we attempted to spotlight on potential climate change consequences on North Africa's livestock sector and possible adaptation measures, it presents a literature overview of some relevant studies and projects on the subject in Morocco. Probable decrease in water and feeding resources associated to heat stress and outbreaks of emergent and re-emergent animal diseases underscore the need to act fast and efficiently through exploring quality data via methodological vulnerability assessment studies. Doing so may point the way towards appropriate adaptation strategies just in time to anticipate potential damages. Not doing so may disturb the fragile livestock's balance between ensuring food security, supporting livelihoods of rural populations and preserving the environment, in a region where the socio-economic balance is already bracketed by this year's wave of the Arab spring.

INTRODUCTION

Morocco ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1995, the Kyoto Protocol in 2002 and hosted the seventh Conference of the Parties in Marrakech (COP 7) where the concluded "Marrakech accord" paved the way for the entry into force of the protocol; it submitted its first national communication in 2001 and the second one in 2010. Table 1 shows that agriculture accounts for almost 33% of national GHG emissions (Second national communication in climate change, 2010).

Table 1: Total GHG emissions from different sectors in 2000 in Morocco
(Adapted from the Second national communication in climate change, 2010)

MODULES	GROSS EMISSIONS		ABSOPRTION		NET EMISSIONS	
	CO2 Eq (Gg)	%	CO2 Eq (Gg)	%	CO2 Eq (Gg)	%
Energy	32 290,82	46,76%	0,00	0,00%	32 290,82	50,90%
Industry	3 772,31	5,46%	0,00	0,00%	3 772,31	5,95%
Agriculture	20 634,03	29,88%	0,00	0,00%	20 634,03	32,53%
Forestry	9 269,66	13,42%	5 623,73	100,00 %	3 645,93	5,75%
Waste	3 096,78	4,48%	0,00	0,00%	3 096,78	4,88%
Total	69 063,60	100,00%	5 623,73	100,00%	63 439,87	100,00%

In the light of the 4^{th} assessement report of the Intergovernmental Panel on Climate Change (IPCC), it seems the consensus is becoming global about climate change being a worldwide threat for all nations; it has no borders and affects many sectors of vital importance such as water resources and agriculture where livestock supports livelihoods and food security of almost a billion of the world poorest people (FAO, 2009). Livestock's contribution to the global greenhouse gas (GHG) emissions has been described in details by the United Nation's

Food and Agricultural Organization (FAO) in the Livestock's long shadow report; the sector accounts for 9% of C02, 35% to 40% of methane, 65% of nitrous oxide and 64% of Ammonia. Several mitigation options to reduce GHG emissions from the livestock sector could be adopted beyond a "business as usual" scenario, through a management system including improved feeding practices, dietary additives, improved manure management, breeding and other structural changes (FAO, 2006).

However, there is a need to understand the feedback loop where livestock is both a significant contributor to climate change but also a victim of its consequences. Livestock occupies 26 percent of the earth's ice-free land surface for grazing while 33 percent of agricultural cropland is used for feed production; it generates less than 2% of the global GDP (Steinfeld, 2006). Livestock accounts for 40% of the global value of agricultural output, and provides 15% of total food energy and 25% of dietary protein; demands for livestock products are expected to increase in a number of developing countries driven by growth in incomes, population and urbanization (FAO, 2009). Changes in climate patterns can have multiple impacts on livestock, including productivity losses due to heat stress, shifting of vector born diseases, increase in feed prices and animal losses due to droughts and floods; leading therefore to increasing prices of food products from animal origin ((Uwizeye, 2008).

Morocco just like other developing countries will pay the bill of GHG emitted by developed countries as historical polluters which had 20% of the world's population in 2004 but accounted for 46% of total global emissions (IPCC, 2007); with agriculture and water resources being the most likely sectors to suffer from climate change consequences in Morocco (Second national communication in climate change, 2010). More droughts and fewer precipitations in a country already threatened by water scarcity are a serious warning. A crisis situation may or may not occur depending on who we believe, on climate change skeptical testimonials of many people or alarmist reports; a growing literature on the subject from well known experts led by the IPCC clearly demonstrates the link between anthropogenic emissions and change in climate patterns. In both cases steps needs to be taken in order to cope with climate vulnerabilities within agriculture; adapting the Moroccan agriculture to climate change means sustaining the livelihoods of its rural populations and consequently contributing to Morocco's socio-economic development. Livestock resources in Morocco are facing the climate change threat across the country. Therefore, the main aim of this analysis is to contribute to the assessment of climate change vulnerabilities within the livestock sector in Morocco. Some appropriate adaptation responses are summarized in this paper; further investigations are outlined in recommendations.

CLIMATE CHALLENGES OVERVIEW IN MOROCCO

Climate

Morocco is located in north-west Africa between latitudes 21°N to 36°N and longitudes 1°W to 17°W and is only 14 km to Europe through the strait of Gibraltar. It's a 710 850 km^2 country bordered west by the Atlantic Ocean (2 934 km), North by the Mediterranean Sea (512 km), South-east and South-west by the Sahara desert. For generally speaking, the Moroccan climate is characterized by hot and dry summer with almost no precipitations and high evapotranspiration; the winter season is mild along coastal areas and cold elsewhere. However, there is climate variability through multiple climate combinations due to Morocco's geographic position and its Atlas mountain ranges topography (highest ones in North Africa and the Arab world) which constitute natural barriers regarding Mediterranean and Atlantic influences. As a consequence, the average annual rainfall varies from 100 mm to 1200 mm; frequent climate patterns range from erratic rainfall to cold and heat waves with unpredictable droughts (Second national communication in climate change, 2010).

The analysis of local temperature observations from 1960 to 2000 points up that the climate is warming all over Morocco with a peak of +1.4 °C in the south east region. Furthermore, it shows an increase in minimal temperatures during a time period of 40 years (Second national communication in climate change, 2010). As for rainfall according to the same source, observations during the last 3 decades from 1976 to 2006 demonstrate a net decrease ranging from 30% to 3% depending on regions. In a recent multi-stakeholders study carried out by the World Bank in collaboration with the FAO and 3 Moroccan institutions (DMN, INRA, MAPM), a statistical downscaling of climate projections established by the IPCC as shown in figure 1 using the HadCM3 climate model calibrated with local observations and large scale data made it possible to move from grid-boxes of 250 km x 250 km to a fine enough size of about 100 km^2 that goes with the scale of the main agro-ecological zones. The output in terms of precipitations (Figure 2a) basing on the A2 scenario indicates that annual rainfall will decrease by 20% from now to 2050 and by 40% in 2080 (only 16% in the Saharan zone by 2080). As for temperatures (Figure 2b) and according to the A2 scenario warming is expected to approach 3°C from now till 2080 with a peak of 5°C in some regions. Consequently the evapotranspiration will increase by 20% from now till 2050 and 40% in 2080 (only 9% by 2080 in the Saharan zone) according to the World Bank (2009).

Agriculture

In the light of these projections it seems that both irrigated and rainfed agricultures are potential victims of climate change and will suffer from drop in precipitations and rising temperatures with rainfed agriculture being the most vulnerable. Possible impacts includes an increasing water demand in irrigated agriculture, shortening of vegetative cycles of cultures, decreasing yields, heavy erosion leading to soil degradation, intrusion of sea water to the aquifer in coastal areas and shifting of the dry zone to the north (Second national communication in climate change, 2010).

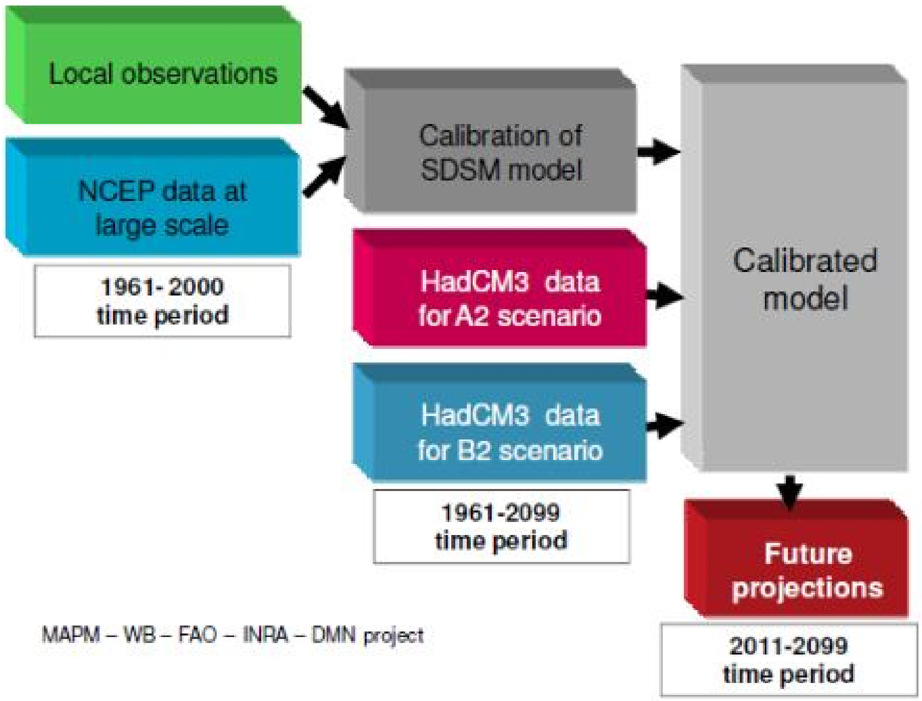

Figure 1: Statistical Downscaling Model (SDSM) (World Bank, 2009)

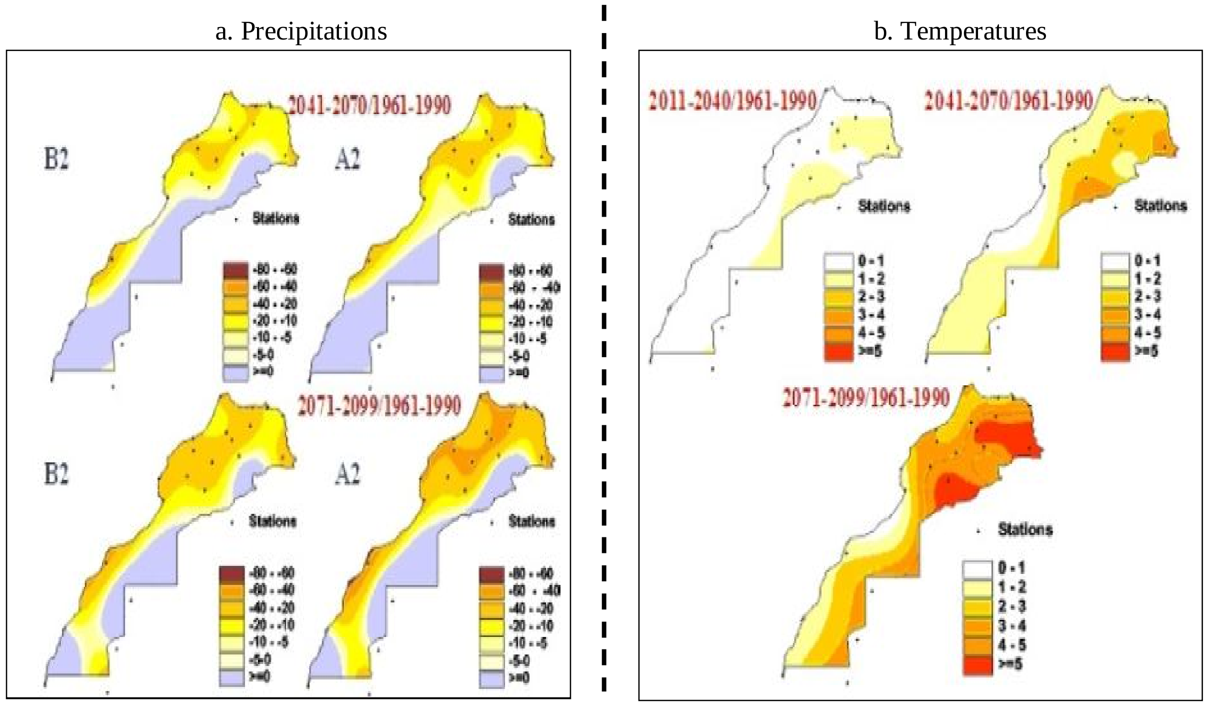

Figure 2: Main climate projections for Morocco (World Bank, 2009)

Livestock

Main livestock of vital socio-economic role within Morocco are ruminants. There are about 2.8 million cattle, 17.5 million sheep, 5.2 million goats and 50 thousand camels. Ruminants produced some 308090 tones of meat (FAO STAT, 2009) and 1769000 tones of milk (FAO STAT, 2008). Other livestock includes 153300 horses, 505200 mules, 962600 asses and honey bees. The poultry (Chicken and turkeys) sector produced some 500000 tones of meat and 244000 tones of eggs (FAOSTAT, 2009). Livestock contribution to GHG emissions in Morocco in terms of methane (CH4) and nitrous oxide (N_2O) are summarized in table 2.

Table 2: GHG emission from different agricultural sources in 2000 in Morocco (Adapted from the Second national communication in climate change, 2010)

SOURCES	**CH_4**		**N_2O**		**CO_2 EQ.**	
	Gg	%	Gg	%	Gg	%
Enteric fermentation	211,99	95,7%	0,00	0,0%	4 875,78	0,0%
Cattle	87,09	39,3%	0,00		2 003,00	
Sheep	76,39	34,5%	0,00		1 756,95	
Goats	24,78	11,2%	0,00		569,83	
Camels	5,80	2,6%	0,00		133,31	
Horses	2,73	1,2%	0,00		62,89	
Mules and donkeys	15,21	6,9%	0,00		349,81	
Manure	8,26	3,7%	4,01	7,6%	1 376,23	7,6%
Cattle	2,57	1,2%	0,00		59,04	
Sheep	2,44	1,1%	0,00		56,22	
Goats	0,84	0,4%	0,00		19,37	
Camels	0,24	0,1%	0,00		5,56	
Horses	0,25	0,1%	0,00		5,73	
Mules and donkeys	1,37	0,6%	0,00		31,48	
Chicken	0,55	0,2%	0,00		12,64	
Storage of manure and pasture/grazing	0,00	0,0%	4,01		1186,20	
Rice growing	1,30	0,6%	0,00	29,90	29,90	0,0%
Agricultural soils	0,00	0,0%	48,49	92,4%	14 352,10	92,4%
Total	**221,55**	**100,0%**	**52,49**	**100,0%**	**20 634,01**	**100,0%**

Morocco's livestock sector needs to move fast towards more efficiency and adopt a resource-friendly attitude. It's the case for example within the dairy sector as the benefit shortfall in terms of competitiveness driven by Morocco's free trade agreement with the EU associated to soaring prices of agricultural supplies are pointing the way in the direction of more improvements counting an optimized productivity/quality system and efficient use of water resources (Sraïri and Chohi , 2007).

Feeding resources: Irrigated perimeters produce most of the feeding that goes into intensive livestock systems, and production in these perimeters was supposed to be independent from climate patterns; however, repetitive droughts during the last decades proved that even irrigated agriculture is not invulnerable to climate change and is even very sensitive due to inefficient water use in irrigation (Morocco's 2nd National Communication, 2010). According to the World Bank recent study on climate change impact on agricultural yields in Morocco (large scale climate projections downscaled to the level of existing agro-ecological zones have been converted into agricultural yields projections and summarized in figure 3 and table 3), the production of fodder crops including irrigated/rainfed fodder-cops and rainfed rangeland is expected to decrease modestly starting from 2030 for both scenarios A2 and B2 (world bank, 2009). As for rangeland, it covers 82% of arid lands in Morocco and is mainly composed of steppes, shrubs, and grassland. Livelihoods of thousands of people rely on these areas threatened by desertification due to human actions combined with climate (Mahyou and all, 2010).

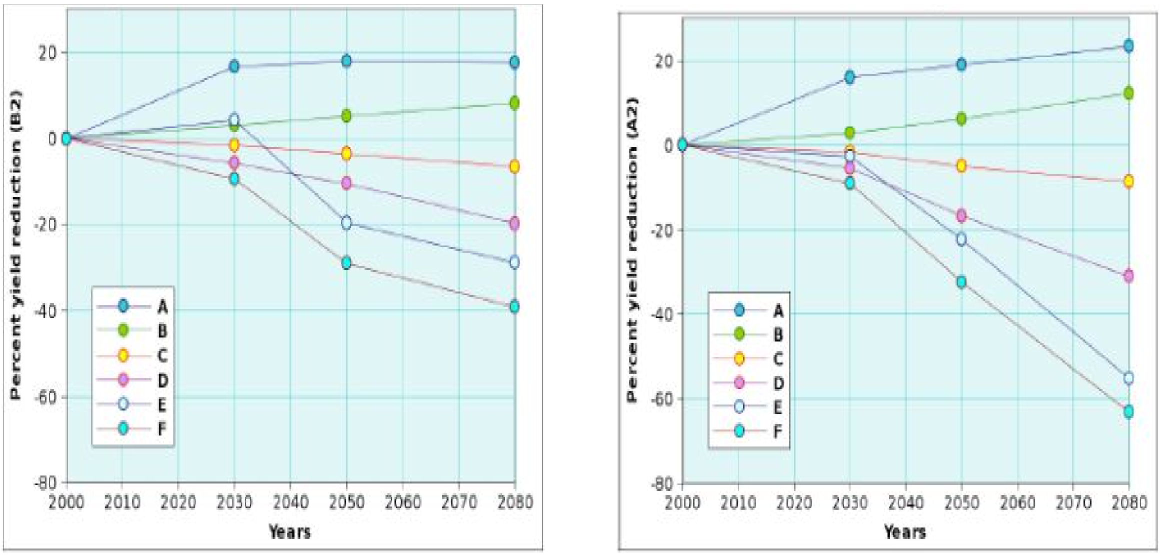

Figure 3: Percentages of yield reductions at different time horizons for 6 crop-groups (World Bank, 2009)

A: Unrelated irrigated crops projected to significantly benefit from climate change B: irrigated fruits and vegetables that will benefit from climate change; C: fodder crops & vegetables that will suffer from climate change very moderately starting in the 2030s; D: rainfed cereals and legumes undergoing a drop of yields of about 5% in 2050 E: wheat and barley (both rainfed) whose yield drops will exceed 20% from 2050 F: rainfed winter crops that will undergo yield losses in excess of 30% by 2050

Rising temperatures and scarcity of water resources due to the decreasing of precipitations and inefficient water use in irrigated agriculture may negatively impact on the availability and quality of fodder resources. If we spotlight in water productivity in Morocco within dairy/meat cattle as shown in a recent study in Tadla region, we need 1.7 m3 of water to produce 1kg of milk and 9.1 m3 to produce 1kg of live weigh gain. Improvement of water productivity in cattle farming could be obtained through good management practices ranging from the use of adapted forage species and irrigation techniques to the formulation of balanced rations and stockbreeding practices; the use of virtual water through off-farm feed resources by unskilled farmers (unbalanced rations) could be useless depending on agricultural supplies prices (Srairi and all, 2009). An efficient multi-stakeholders integrated management approach including dairy plants, dairy farms and irrigations schemes could be developed if supported by a research-action strategy; one critical pillar of such a plan is conceiving a feeding system under water constraints as tendencies are towards maize silage supposed to be less water consuming than Lucerne (Le Gal et al., 2007).

Table 3: Impact class c, percentages of change in yield, water consumption and yield distribution patterns between baseline and 2050 (World Bank, 2009)

Scenario	Variable	Agroecological zone					
		DEF-or	DEF-sud	FAV	INTERM	MONT	SAH
A2	(1)	−4.00	−3.63	−7.25	−5.33	−4.60	−4.00
	(2)	13.71	10.25	14.75	16.00	12.40	10.25
	(3)	0.06	0.09	0.19	0.14	0.16	0.11
	(4)	7.00	2.00	2.38	9.33	−4.20	−1.75
	(5)	−13.14	−6.00	−10.13	−10.00	−5.40	−5.00
	(6)	−42.86	−22.88	−15.75	−29.33	−7.20	−10.00
B2	(1)	−5.14	−3.00	−5.13	−5.33	−2.40	0.25
	(2)	12.57	8.75	14.38	13.00	12.40	7.00
	(3)	0.10	0.08	0.16	0.10	0.14	0.10
	(4)	4.14	5.25	6.50	10.67	−3.00	1.00
	(5)	−13.29	−8.38	−9.13	−10.50	−2.60	0.25
	(6)	−36.43	−27.63	−22.38	−35.33	−5.00	1.00

(1) % yield change
(2) % change in water requirements
(3) Low yields probability
(4) % change of 1st yield decile
(5) % change of 9th yield decile
(6) % change of yield interdecile

Food and water deprivation: According to the researches on the Moroccan black goat, a milk production of about 700ml/day decreased by 30% after 2 days of thirst, and it losses 5% of body weight after 2 days of starvation. The Draa goat is another example, where two days of water starvation resulted in 21% decrease in dry matter intake (Hossaini and Benlamlih, 1993; Hossaini and Mouslih, 2002).

Heat Stress: Chase defined heat stress as the point where the cow cannot dissipate an ample amount of heat in order to maintain body thermal balance. Effects of heat stress may be mild changes in milk production and metabolism or even potential cow death. The temperature humidity index (THI) is used to calculate environmental conditions that induce a situation of heat stress with THI = (Dry bulb temperature C°) + (0.36* dew point temperature C°) +41.2 (Chase, 2006). Main heat stress effects on dairy cattle are summarized in table 4.

Health: Some indications that might be considered to predict which diseases can emerge in Morocco due to climate change could came from taking into account livestock diseases emergent or established in places that have climate similar to what projected for Morocco in the future. According to the world animal health organization (OIE) questionnaire survey which targeted 126 countries including Morocco to identify emergent and re-emergent animal diseases, table 5 shows a list of 15 diseases that were believed to be associated with climate change or environmental change (Black and Nunn, 2009). The west Nile fever is among these diseases; it was clinically suspected and then confirmed through laboratory analysis by national veterinarian laboratories and the OIE international laboratory in Italy; an official press release published by the National office for animal health and food safety (ONSSA) states that "the emergence or re-emergence of this disease in certain areas might be related to climate changes observed during the last years, which seems contributed to viral activity increase and extension of the mosquito vector's distribution areas" (ONSSA, 2010).

Table 4: Effect of heat stress on dairy cattle (Adapted from Chase, 2006)

	Effects
Physiology	- Elevated body temperatures - Increased respiration rates - Increased maintenance energy requirements - Increased loss of sodium and potassium
Milk production	- Decreased efficiency of nutrient utilization - Decreased dry matter intake - Decreased milk production
Reproduction	- Decreased length and intensity of estrus period - Decreased conception rate - Decreased growth, size and development of ovarian follicles - Increased risk of early embryonic deaths - Decreased fetal growth and calf size

Table 5: List of animal diseases that were believed to be associated with climate change or environmental change [1](Black and Nunn, 2009); [2](OIE WAHID, 2010)

Emergent/re-emergent diseases[1]	Last occurrence in Morocco[2]
Blue tongue virus	12/2009
Rift Valley fever	-
West Nile virus	2003
African horse sickness	10/1991
Lumpy skin disease	-
Leishmaniasis	04/2006
Epizootic hemorrhagic diseases	10/2006
Tick-borne diseases	-
Parasitic diseases	-
Pasteurellosis	-
Avian Influenza (highly pathogen)	1983
Anthrax	09/2009
Blackleg	-
Rabies	2010
Tuberculosis	2010

Key factors to take into consideration in order to understand how climate change could affect livestock diseases are (Gale and all, 2008):

- Molecular biology of the pathogen (his aptitude to mutate and respond to opportunities arising from climate change)
- Vectors (Change in climate could affect the geographical range and abundance of vectors; a pathogen may also be transmitted by new vectors)
- Farming practice and land use

- Zoological factors (climate change could lead to abundance of vertebrate hosts and reservoirs, change in behavior and interaction with wildlife, movement and distribution of wildlife)
- Environmental factors (temperature, humidity and sunlight affect pathogens that are able to survive outside a host in the environment)
- Establishment of new micro-climates and micro-environments (= micro-habitats)

METHODOLOGY

A literature review on livestock's interrelations with agriculture and climate change has been performed to assess potential climate change vulnerabilities within the livestock sector in Morocco. Many resources were explored including the statements made by globally produced reports, locally produced studies, and projects within Morocco that are either in progress or are completed. Within the Moroccan context, almost all the quantitative and qualitative studies performed to date focused mainly on the assessment of climate change impacts on agricultural yields of crop families of major socio-economic importance such as cereals. As for livestock considered as a secondary agricultural-related sector, few momentary analyses have been done to assess climate vulnerabilities in livestock species within Morocco. Main findings about climate change impacts on feeding resources, livestock production, and animal health are summarized in the result section. It's extremely difficult to assess the actual level of confidence of theses impacts on the Moroccan livestock sector due to lack in available data and adapted methodologies; however it's a starting point that spotlights on livestock‘s situation from a climate change perspective in Morocco towards further investigations on this issue in the future.

RESULTS AND DISCUSSION

In order to apprehend the climate change vulnerabilities in livestock sector, the study considers different production systems. One way of doing it as adopted in this analysis is by considering the following:

Cattle, we considered 3 widespread systems within this sector: 1/ *Intensive system* (imported and crossbreeds consuming mainly fodder crops produced in irrigated perimeters; milk and meat are systematically marketed) 2/ *Mixed system* (improved breeds with grazing and limited contribution of irrigated fodder crops; production output is mainly marketed) 3/ *Extensive system* (mainly local breeds with feeding based on grazing and crop by-products; small quantities of milk are consumed locally and fattened animals are sold); Sheep and goats, there are 3 different systems that could be identified as: (i) *Pastoral system* (dominated by grazing and use of local breeds) (ii) *Agro-pastoral system* (in addition to grazing there is a large farm contribution to feeding (iii) *Oasis system* (based mainly on cut-and-carry Lucerne) (adapted from Guessouss, 1991).

Table 6: Strengths/weaknesses of the ruminant sector and its probable vulnerabilities in a climate change situation

		Ruminants (cattle, sheep & goats)			
		Intensive	**Mixed/Agro-pastoral**	**Extensive/Pastoral**	**Oasis**
S T R E N G T H S	***Feeding***	- Good feeding management practices - Balanced ration based mainly on fodder crops produced in irrigated perimeters	- Diversified feeding calendar including grazing and significant contribution of fodder crops and farm products	- Based mainly on low cost resources including rangeland grazing and crop-by products	- Based mainly on cut-and-carry Lucerne produced in irrigated and fertile oasis.
	Animal Health	- Efficient prophylactic and therapeutic follow up - High reproduction aptitudes	- Improved veterinarian services - Enhanced reproduction potential	- Health care calendar limited to de-warming treatments and state funded vaccinations	- Exceptionally prolific local breeds (D'man sheep and Draa goat)
	Socio-Economic role	- High production potential - Milk and meat are systematically marketed - -> high economic profitability and vital role in national food security	- Enhanced growth and productivity of milk and meat - Outputs mainly marketed - -> important source of income and nutrition for stockbreeder's households.	- Main source of food and income for millions of rural populations	- Significant contribution to food security and livelihoods of oasis's populations
WEAKNESSES IN CASE O C L I M A T E C H A N G	***Feeding***	- Slight decrease in irrigated fodder crops productivity and high water pricing for irrigation - -> feeding shortage	- Decrease of rangeland grazing potential, low yields of fodder crops and adjusted pricing for irrigation water - -> feeding shortage and competition over resources	- Lack in water/ pasture resources associated to unaffordable feed prices will lead to overgrazing and nomadic stockbreeding - Competition over pasture lands and water resources - -> resources-use conflicts and social instability	- Humans/animals competition over grains and water resources

	Heat stress	- Imported breeds highly vulnerable to heat stress - Decrease in feed intake -> significant drop on growth, reproduction aptitudes and productivity performances (particularly in dairy cattle)	- Crossbreeds vulnerable to heat stress - Decrease in growth, production and reproduction outputs	- Local breeds relatively adapted to heat stress - Significant growth and productivity losses	- Local breeds relatively adapted to heat stress - Significant growth and productivity losses
	Animal Health	- Selected breeds are highly sensitive to diseases -> high risk in case of outbreaks of (re)emergent diseases	- Crossbreeds significantly sensitive to animal diseases -> threat in case of outbreaks of (re)emergent diseases	- Local breeds significantly resistant to animal diseases	- Local breeds significantly resistant to animal diseases
	Socio-Economic effects	- Additional costs for methane and manure management, feeding shortage and emergent disease control -> Less profitability - Decrease in production -> Food security risks	- Environmental and animal health costs - Competition over resources -> conflicts - Relatively expensive prices of industrial feed -> limited benefice margin	- Low productivity associated to animal losses due to high vulnerability to climate hazards such as floods -> economic losses - Hunger and poverty leading to rural exodus - Accelerated deforestation and desertification	- Social conflicts over the use of water resources - Hunger and poverty leading to rural exodus - Accelerated deforestation and desertification
CLIMATE CHANGE VULNERABILITIES	Short term				
	Medium term				
	Long term				

Slight → Moderate → High → Severe

In the light of these findings the following assumptions could be made:

Feeding resources: Pastoral systems are the most likely to be severely impacted by climate warming; thus significant competition over pasture resources might occur within systems relying mainly on grazing such as extensive and pastoral systems. The same hypothesis is applicable to the oasis system, it's assumed that feeding resources may be highly to severely vulnerable to climate change; since this fragile ecosystem has been reported to became defenseless against rainfall hazards due to water scarcity and decreasing groundwater resources for irrigation purposes (Mahe, 2006). Even feeding systems based mainly on irrigated fodder crops could be slightly or moderately affected as fodder production may decrease starting from 2030. Another factor of vulnerability that should be considered is the price of industrial feed since it's constantly incorporated into feeding calendars especially during drought periods; increasing competition with the bio-fuel sector such as maize used as feedstock for ethanol production, associated to high prices of fossil fuels (pollution taxation) could lead to economically unaffordable industrial feed prices for stockbreeders. Several appropriate adaptation measures to be mentioned here are planned within the PMV such as water saving practices including drop irrigation, recasting fodder crop's agricultural calendar, use of complementary irrigation and climate adapted fodder crops varieties. Nevertheless, accurate actions are needed in terms of better grazing management practices and protection of dry pasture lands, as well as long-term research-action strategies.

Heat Stress: improved breeds are on the top list of vulnerable livestock to heat stress; projected losses in production and reproduction performances could unbalance the economic effectiveness of formal market oriented stockbreeding units, and affect national food security. As for domestic and small scale livestock production systems, even if local breeds could have exceptional adaptive capacities to heat stress and water/food deprivation, stockbreeders may see their small benefice margin disappear impacting therefore on their livelihoods and survival. Necessary adaptation actions start by introducing some ration adjustments and providing enough quantities of fresh water, as well as improving feeding management practices by distributing fresh, palatable and high quality feed during cooler times in the day; as for animal housing some adjustments could be done such as minimizing overcrowding, making shade available for animals and increasing the air flow through good ventilation (Chase, 2006).

Animal Health: worldwide outbreaks of emergent and re-emergent animal diseases have been closely monitored due to their socio-economic costs and their consequences on international trade. There is a growing fear about the role that may play climate and environmental changes in multiplying and spreading these diseases beyond their current distribution areas. The recent outbreak of west Nile fever indicates that Morocco is not an exception. The first step towards adaptation is by understanding how climate change could affect livestock diseases within the Moroccan context through oriented research programs that will enable developing a risk based framework to screen for organisms that could have high likelihood to emerge as a consequence of climate change and to identify any endemic pathogens or vectors that might be affected if the climate changes (Gale and all, 2008).

CONCLUSION AND THE WAY FORWARD

As a consequence of the projected changes in climate patterns in Morocco the livestock sector may face serious threats in terms of availability and quality of feeding resources especially in dry rangeland, oasis and rainfed agro-ecological zones. During drought periods, water and food deprivation associated to heat stress will impact negatively on animal reproduction and production performances. Emergent and re-emergent animal diseases driven by climate and environmental changes could have disastrous consequences on receptive animals. Climate change vulnerabilities within the livestock sector are warning signals to food security and livelihoods of the wide community of Moroccan stockbreeders and other stakeholders within the livestock-agricultural cluster. These signals should be interpreted in due time to come up with an integrated livestock preventive adaptation response starting by reducing its water footprint while increasing its productivity. However, prior to any adaptation strategy, methodological tools and models needs to be developed and adapted through a multidisciplinary research approach in order to conduct detailed vulnerability assessments through a cascade of interlinked livestock related sectors including climate, hydrology, agriculture and animal health.

Depending on funding possibilities, this analysis could serve as a substantial asset to build on positive synergies and partnerships with national/international institutions and development agencies towards conceiving and implementing small scale pilot adaptation projects. The main focus will be on highly vulnerable livestock systems i.e. extensive (see figure 4) and oasis systems; a special attention will be given as well to minor livestock species such as honey bees. In addition to climate change resilience the expected outcome is twofold: first such projects are entry point to end poverty and sustain livelihoods of rural underprivileged populations; second, it's a valuable option to preserve the genetic capital via local breeds' valorization including the Draa goat, D'man sheep, Atlas/Oulmes cattle and the Saharan bee "Apis mellifera sahariensis".

Figure 4: Extensive small ruminants herd grazing in TAFRAOUAT - southern Morocco

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LIST OF USED DEFINITIONS AND ABBREVIATIONS

- DMN: Direction de la Météorologie Nationale / National Meteorological Authority.
- GHG: Greenhouse Gas
- HadCM3: model of the United Kingdom's Met Office Hadley Centre.
- INRA: Institut Nationale de la Recherche Agronomique / National Institute for Agricultural Research.
- MAPM: Ministère de l'Agriculture et des Pêches Maritimes/ Ministry of Agriculture and Fisheries.
- OIE: World Organization for Animal Health
- PMV: Plan Maroc Vert / Morocco's agricultural green plan.
- IPCC: Intergovernmental Panel on Climate Change.
- Climate scenarios: families of possible futures covering the atmospheric conditions which will result from our policy choices, ranging from drastic measures for emissions reduction which would follow rapid adoption of renewable energy, to an acceleration of fossil fuels use in developing countries.
- A2 scenario: globally inhomogeneous economic development with a medium-high rise in GHG; the underlying theme is high population growth, and less concern with rapid economic development.
- B2 scenario: emphasis is on regional economic, social and environmental sustainability with slower but continuous increase in the world's population and a medium to low rise in GHG.